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We are concerned with the problem of establishing a replacement-parts policy for a project. For our purposes a project has the following characteristics: It consists of a sequence of operations that are performed on an expensive piece of equipment; these operations can give rise to demands for replacement parts for the equipment; the project has a well defined beginning and end: the primary objective is to satisfactorily complete the project without too much delay. Such projects are typified by prelaunch operations for a space shot and, perhaps, the modification of an aircraft.

In general, replacement parts are available from (a) stock on hand, (b) local bench repair of malfunctioning parts, (c) remote sources such as depots or manufacturers, and (d) cannibalization or rob-back from other equipment. A replacement-parts policy is a strategy governing the use of these sources. More specifically, a parts policy should at least specify (a) stock levels, (b) bench repair facilities, (c) priorities for drawing spares, (d) reorder schedules, (e) stock locations, (f) rules governing the use of cannibalization and rob-back. In order

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This paper is a summary of the presentation given at the Depot Scheduling and Control Conference held on 1-3 December 1964 at The RAND Corporation, Santa Monica, California. A more complete discussion will be published in a forthcoming RM, "A Network Approach to Parts Provisioning for Apollo Pre-Launch Operations."

to select from among policies or even to evaluate one policy, it is necessary to have both a measure of effectiveness and a measure of cost. Given the primary objective of the project, the measure of effectiveness of a parts policy should be in terms of the amount of delay (or rather the probability distribution of delay) in the schedule. The measure of cost must reflect at least the cost of establishing and maintaining the stock levels and repair facilities corresponding to the replacement-parts policy.

The above characteristics of a project suggest the following two special features which differentiate it from many other inventory problems. First, a project consists of an operations plan that specifies the sequence of activities or tests to be performed. It is during these tests that malfunctions are identified and demands for parts are generated. To the extent that the operations plan is specified, the location in the plan where a demand for a particular part can occur may be identified. For example, a demand for a guidance package is much more likely to occur during a functional checkout of the guidance control system, than during a pressure checkout of the fuel system. Second, the relation between parts shortages and effectiveness is complicated. It is easy to construct examples of parts shortages which cause little or no delay in the schedule because subsequent activities can continue without the part. Conversely, it is possible to construct examples of shortages which stop all operations. Actually, the effect of a parts shortage on delay depends not only on the length of time the shortage exists, but also on where in the schedule the demand occurs and where in the schedule the demand must be filled. The effect of one shortage may also be complicated by the occurrence of other shortages.

Our approach to evaluating a replacement-parts policy is to represent the scheduled operations as a project network. During these scheduled operations various non-scheduled activities are performed. For our purpose, the significant non-scheduled activities are those associated with replacing malfunctioning parts, e.g., bench repair. We represent these activities by adding arcs to the original network. The manner in which these arcs are added and the times associated with them are functions of the particular parts policy being evaluated.

We have developed a Monte-Carlo computer model for evaluating different replacement-parts policies in a project context. The input to the model consists of a description of the schedule of operations in PERT network form, a list of parts, and a list of "possible demands." Each part is characterized by the quantity stocked and the time required to repair a defective part, (this time can alternatively be interpreted as a reorder time for the part.) Each possible demand is characterized by where in the network the demand can occur, where it must be satisfied, which part is demanded, and the probability of occurrence. The output is a frequency distribution of the event times for each node in the network (i.e. distributions of the earliest time that each operation can be started).

The model consists of three main components: a demand generator, a demand interpreter, and an evaluator. In the course of one iteration the generator determines, by means of random draws, which of the possible demands will actually occur. The interpreter adds arcs to the original network. The added arcs represent activities necessitated by the demands,

(e.g., bench repair activities.) The evaluator computes the earliest time for each node in the augmented network. In this way each iteration produces one observation for each of the frequency distributions that form the output. This procedure, when combined with stratified sampling techniques in the demand generator, seems sufficiently efficient to permit comparisons among a large number of policies.